Atmospheric Propagation Analysis -Gotland, Sweden

Rowena Carlson
SPAWAR Systems Center San Diego D743
53560 Hull Street
San Diego, CA 92152-5001
phone: (619) 553-2505 fax: (619) 552-6842 email: rcarlson@spawar.navy.mil
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LONG-TERM GOAL

Many new high resolution thermal imaging systems are being produced for the U.S. Navy which will operate primarily in the coastal warfare regions. Submarines and small coastal boat platforms present an optical imaging geometry along a horizontal path only a few meters off the surface of the ocean. It has been found that little or no spectral data exists on the atmospheric transmission which can be expected in the marine atmospheric boundary layer (MABL) for this special imaging geometry. Some broad band transmission data has been collected at 3-5 and 8-12 μm. It has been found that the atmospheric propagation models such as LOWTRAN 7 and MODTRAN do not adequately model the broad band data in this region of the atmosphere and so are also questionable at higher spectral resolutions. Higher spectral resolution data or accurate modeling capability is necessary as system designers attempt to band optimize for certain atmospheric conditions and targets. As a result of this data and model deficiency, the Atmospheric Propagation Analysis (APA) program was developed at Naval Command, Control and Ocean Surveillance Center, Research, Development, Technology and Evaluation Division (NRaD) in San Diego. The APA program conducts spectral measurements of atmospheric transmission in the thermal infrared across a horizontal path over the ocean surface.

The APA program has made a series of transmission measurements at several different sites which provided a variety of environmental conditions. In order to bound the problem, the first measurements were made in the cold and dry conditions of Adak, Alaska, and the hot and humid conditions of Pensacola, Florida[1]. Measurements under intermediate conditions were made in cool and relatively humid conditions in Vindeby, Denmark[2]. The most recent measurements were made in the Baltic Sea on the small island of Ostergarnsholm located 4 km off the east coast of the island of Gotland, Sweden. These measurements were made in conjunction with the Air Sea Exchange Process Study (ASEPS) program organized by the Risø National Laboratory, Department of Meteorology and Wind Energy, Roskilde, Denmark. This program provided detailed information on the environmental parameters of the site which can be related to the atmospheric transmission measurements and propagation model parameters.

This Atmospheric Propagation Analysis (APA) work sponsored by Dr. Steven Ackleson in Atmospheric and Ocean Optics is a step towards the long term goal of accurate atmospheric transmission prediction in the coastal MABL. The data collected under this program will be used to validate and improve existing atmospheric propagation models.

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SCIENTIFIC OBJECTIVES

One of the objectives of the ONR Atmospheric and Ocean Optics Program is to understand the optical properties and processes of the MABL. In support of the MABL work, the current APA Program objective is the quantitative definition of atmospheric degradation encountered in thermal imagery in both the 3-5 μm and 8-14 μm wavebands along a typical naval imaging environments and pathlength.

APPROACH

The APA measurements were made in conjunction with the Air Sea Exchange Process Study (ASEPS) at the site of a meteorological mast maintained by the University of Uppsala. The purpose of ASEPS is to develop paramaterizations of air-sea exchanges in the MABL by measuring and evaluating the physical properties of the MABL. The Uppsala meteorological mast provides wind speed from four heights, wind direction at two heights, air temperature, water temperature, wave height, and current. Other relevant ASEPS measurements include aerosol size distribution (TNO Physics and Electronics Laboratory, The Hague, The Netherlands) and chemical composition (University of Indiana), and concentrations of atmospheric gases (Risø National Laboratory, Roskilde, Denmark). The ASEPS and APA concurrent measurements provide a unique opportunity to not only measure atmospheric transmission but possibly explain what parameters are effecting the spectral content of the measurements.

The APA technique for measuring atmospheric transmission involves measurement of the signal received over the transmission path from a blackbody source. A CI Systems Model SR-5000 infrared spectrometer is used to measure the signal from the source collimator. This spectroradiometer covers the 1.0 to 14.5 μm wavelength region of the electromagnetic spectrum with the use of a circular variable filter wheel. The average spectral resolution is 0.018 μm in the 3-5 μm region and 0.06 μm in the 8-14 μm region. A complete spectral scan is accomplished in approximately 13 seconds. During each data collection period a series of 5 spectral scans were made approximately every 10 minutes. These 5 scans were then averaged in order to reduce any noise effects.

The collimated source includes a 5-inch diameter, clear-aperture collimator, CI Systems Model SR-9, with a 38-inch focal length optical system. This collimator system incorporates a two-optical element Newtonian telescope system with a 5-inch diameter, off-axis, parabolic mirror and a 1.5-inch focusing secondary mirror. The blackbody source included in the collimator system is a CI Systems, Model SR-2-33. Emissivity of the source is 0.99. Operating temperature is 1000 °C ±1.5 °C.

The 5-inch collimator system is placed at one side of an ocean inlet and the IR Spectroradiometer is placed at the other side of the inlet. All instruments are placed at a height above sea level of approximately 2 meters. Infrared radiance from the blackbody source is recorded across the path during a period of documented atmospheric conditions.

Transmittance is calculated as the ratio of the signal response of the long path length over the signal response of a shorter path length. The transmission path length at the Ostergarnsholm site was 908 m.

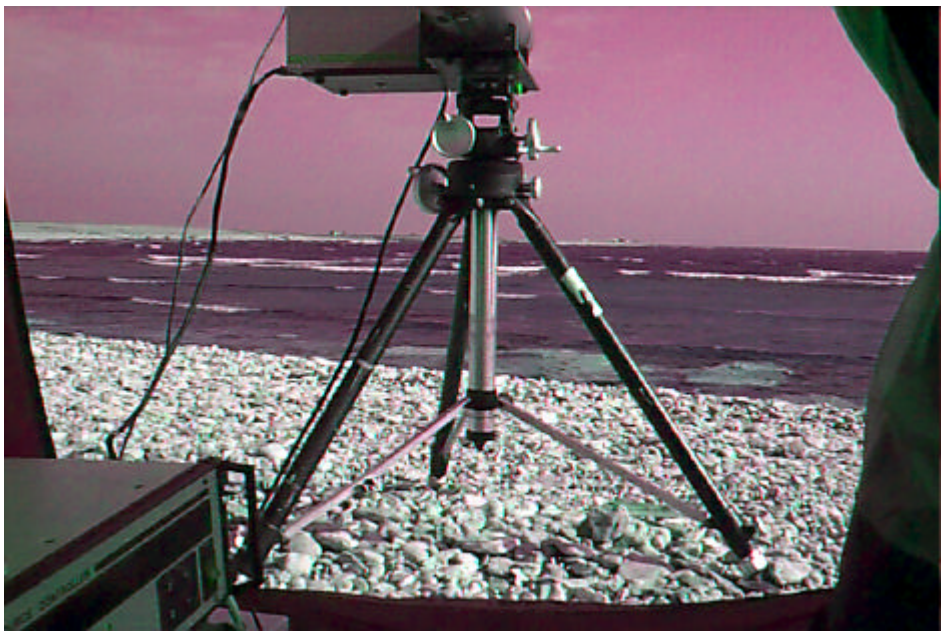
The preliminary transmission results will be relative to a single short path measurement. Investigations are being made into calibrating the spectroradiometer so that detected irradiance can be used to calculate absolute transmittance as a percentage of the known source radiance.

The resulting plots of atmospheric transmission vs. wavelength are then correlated with environmental data provided by ASEPS. On a large scale, the transmission measurements are related to changes in bulk meteorological parameters. On a smaller scale the spectral transmission measurements are related to the aerosol particle size distribution and chemical composition.

WORK COMPLETED

The Gotland deployment was completely successfully under conditions which ranged from low to high wind speeds, cold to moderate air temperatures, and low to high humidity. Data was collected under the high wind speed, long sea fetch data conditions expected at this site. Figure 1 is a photograph showing the transmission path under the high wind conditions of 10 May.

Figure 1. View looking south down transmission path on 10 May 1997.



Transmission data was collected over an 11 day period beginning 3 May 1997. 7 days of data were collected during the measurement period. Equipment problems and storms prevented data collection on all 11 days. Table I gives a summary of the conditions encountered during each measurement period.

The transmission data has been processed and correlated with bulk meteorological parameters. A preliminary data analysis meeting with TNO/FEL has also been completed for evaluation of the aerosol particle size distributions and extinction coefficients calculated from the aerosol data.

Table 1. Environmental Conditions for Measurement Periods.

Date and Time (GMT)	Environmental Conditions	Comments
3 May 1997 1000-1430	Wind speed 14 m/sec then decreasing to 4 m/sec, fetch from over island, white caps.	Algae bloom in shallow water at North end of long path.
4 May 1997 0830-1400	Wind speed 5-7 m/sec. Fetch over island until 1000 GMT then shift to long sea fetch.	Very fast wind shift at 1000 GMT.
8 May 1997 0830-1500	Light wind from south, 2-5 m/sec. Sunny, few high clouds, warm! Clouds increasing after noon.	Scintillation visible.
10 May 1997 0930-1530	Wind speed 10-14 m/sec, long sea	Fog from 1100 to 1345

	fetch. Small waves breaking on beach, white caps.	GMT.
11 May 1997 0900-1430	Wind seed 6-9.5 m/sec, long sea fetch. Small waves breaking on beach, white caps.	
12 May 1997 0800-1230	Wind speed 4 to 8 m/sec, long sea fetch. Sunny, few high clouds.	
13 May 1997 0930-1330	Wind speed from 1.5 to 5.5 m/sec. Light and variable until 1000 GMT then sea breeze from SW, then from East at 1200 (over island).	At 1230 steam rising from algae piled up on beach in front of long path collimator.

RESULTS

Preliminary analysis of the time plots of relative transmission and bulk meteorological parameters has been done. A preliminary analysis of time plots of aerosol particle size distribution and extinction coefficients has also been completed. Preliminary analysis shows strong correlation's between aerosol size distributions and transmission results during some measurement periods. Some measurement periods do not correlate and so require further analysis. A revised analysis plan has been devised with TNO/FEL and the next data analysis meeting will occur in December 1997.

IMPACT/APPLICATION

This is one of the first spectral transmission data sets which has been taken concurrently with measurements of aerosol particle size distribution, aerosol chemical composition, absorbing gasses such as CO2 and ozone, and bulk meteorological parameters. This is also one of the first data sets collected under the high wind conditions frequently found at northern latitudes. This will be an important data set for validating the propagation models under high latitude conditions.

TRANSITIONS

With the publishing of this work in open scientific literature, we hope to accomplish the bulk of the transition of this data to the scientific community. An abstract has been submitted and accepted to present the results of this work at AGARD, March 1998. TNO/FEL will present the paper. The data will also be provided to Dr. Kusiel Shifrin, Oregon State University, in support of his work on inverting transmission measurements to derive aerosol particle size distributions.

RELATED PROJECTS

Air Sea Exchange Process Study (ASEPS) - The APA Vindeby data collection effort was done in conjunction with ASEPS. ASEPS measurements included aerosol particle size distribution and composition, trace gas concentrations, and meteorological and oceanographic parameters.

EO Propagation Assessment in Coastal Environments (EOPACE) - Lessons learned in Vindeby were applied to EOPACE surf zone measurements. Further lessons learned at EOPACE will be applied to future APA deployments. Both data sets will be useful for differentiating between surf zone and non-surf zone effects on transmission characteristics.

REFERENCES

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